The accuracy of nutrient foramen vs. midshaft measurements of the tibia for sex determination

Ashley Dafoe[1,2], David Hunt[1]

[1]National Museum of Natural History, Smithsonian Institution , [2]University of Wyoming

REU Site, EAR - 1560088

Introduction

The use of the postcranial skeleton for sex determination of an individual has had ongoing review and re-assessments to increase the accuracy of these methods. One such method for the tibia is discriminant function analysis [2, 3, 4, 5] which in most cases includes variables of diameter taken at the location of the nutrient foramen. Interestingly however, it is well known that the location of the nutrient foramen varies from person to person and can be located in different areas of the bone from the right to left tibia in the same individual (Figure 1). This has led some standards to adopt several midshaft based measurements in place of or in addition to the existing nutrient foramen based measurements[6, 7].

Research Questions

1. Is intra-person variation in the location nutrient foramen great enough to cause significant mismatching of tibias when discriminant analyses of left tibiae are applied to right tibiae?
2. In light of changes in the Forensic Databank tibial measurements[6, 7], is there an advantage to using measurements collected at the midshaft in addition to, or in place of, measurements collected at the level of the nutrient foramen?

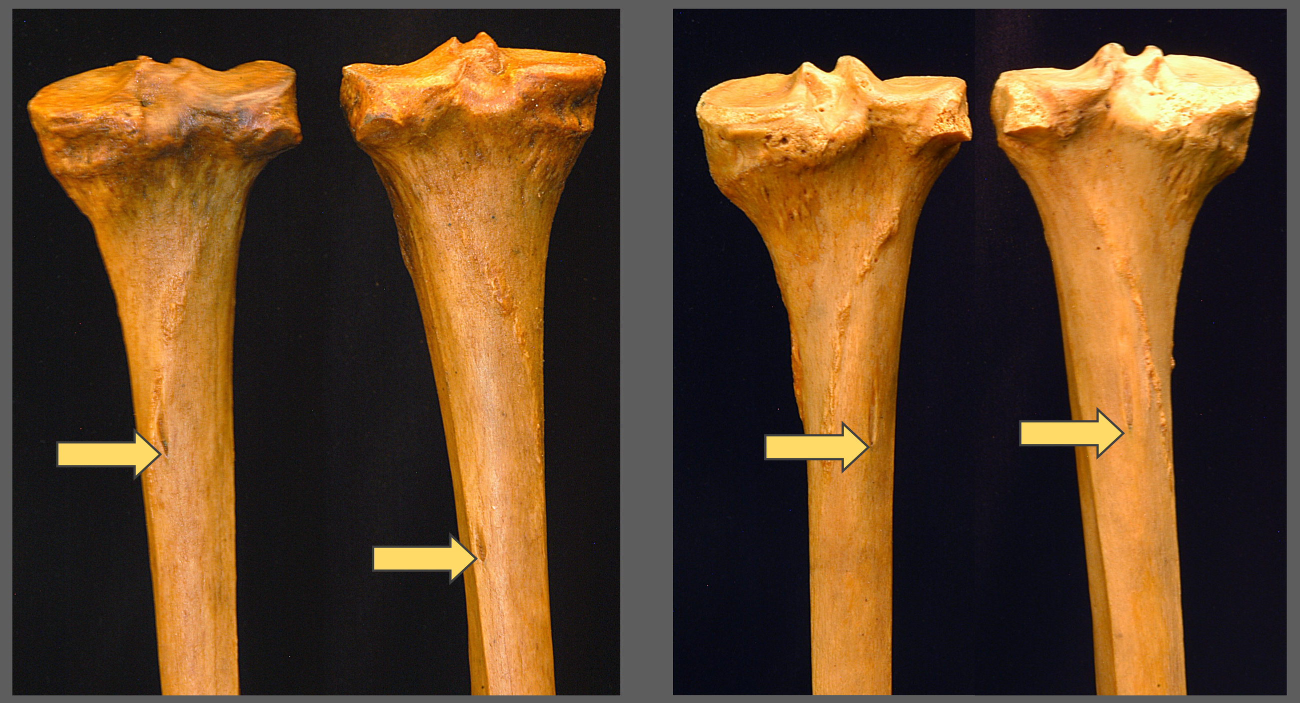

Figure 1. Paired tibiae displaying presence (left) and absence (right) of intra-individual variation of nutrient foramen location.

Methods

Measurements were collected from a sample of 400 individuals (100 White females, 100 White males, 100 Black females, and 100 Black males) from the Robert Terry Anatomical Skeletal Collection. Measurements of the tibia were taken using an osteometric board, sliding calipers and cloth measuring tape according to the standards osteometric protocols [1, 6, 7] (Figures 3,4,5, and 6). Because of discrepancies in the aforementioned standards, medial-lateral diameter at the nutrient foramen was collected both in a 90 degree rotation from the anterior posterior measurement[7] and from the interosseous crest[1].

The data was randomly divided into a testing set and a training set, each consisting of 200 individuals with 50 from each demographic. Several different discriminant function analyses were run in the statistical programming environment R, using only left measurements or left and right measurements from the training set. The resulting discriminant function (LDA) was applied to sex individuals from the testing set using left and right measurements combined. Three variables – maximum length and proximal and distal epiphyseal breadth – were included in all runs. Additional variables were added in the combinations found in Table 1. Initial tests of ancestry differences proved to show no significant differences, and thus ancestry groups were pooled.

Results

1. As seen in Table 2, there is no significant difference in accuracy between a discriminant function created with only lefts and applied only to lefts and the same function applied to lefts and rights. This shows that there is not enough intra-person variation in nutrient foramen location between right and left to cause significant mismatching.

2. The statistical analyses showed that breadth measurements of the proximal and distal epiphyses were consistently good predictors with loading values higher than in all input combinations (Figure 10). Of the two medial lateral measurements collected, the measurement taken from the crest was a slightly better predictor of sex than measurements taken at a 90 degree rotation from the anterior posterior measurement (Figure 8). Of the measurements taken at the midshaft, minimum diameter and circumference were both considered good predictors (Figure 9). In the combined analysis medial -lateral diameter at the nutrient foramen, minimum at the midshaft and circumference at the midshaft were the best predictors. These results show that there is no significant advantage to determining sex based on measurements taken at the nutrient foramen compared to those taken at the midshaft (Figures 5-7).

Table 2. Percent of individuals in testing sets accurately sexed

	NF 90 degrees	NF crest	Mid-Shaft	Combined
Left applied to Left	90%	90.5%	88%	89%
Left applied to Right	90%	91.5%	89%	89%

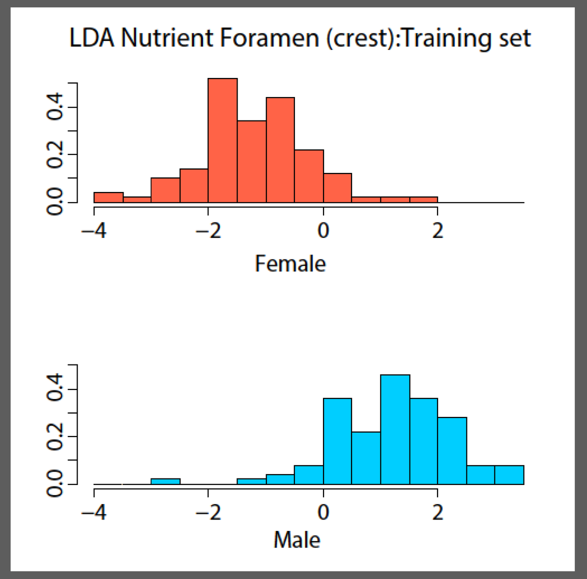

Figure 5. Linear Discriminant Analysis (LDA) of diameter at the nutrient foramen

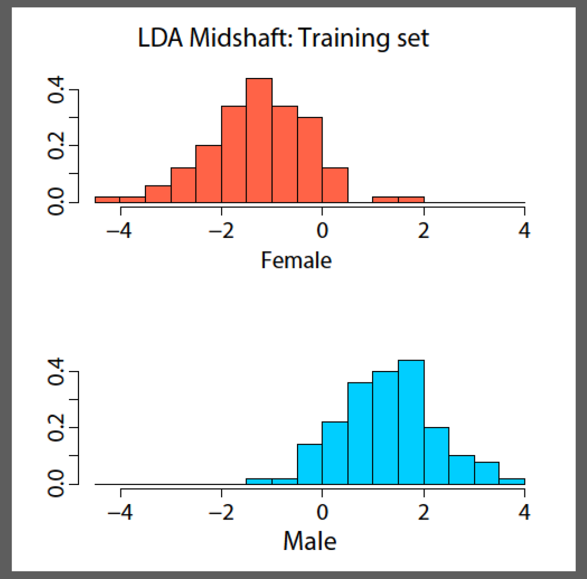

Figure 6. LDA of diameter at the midshaft

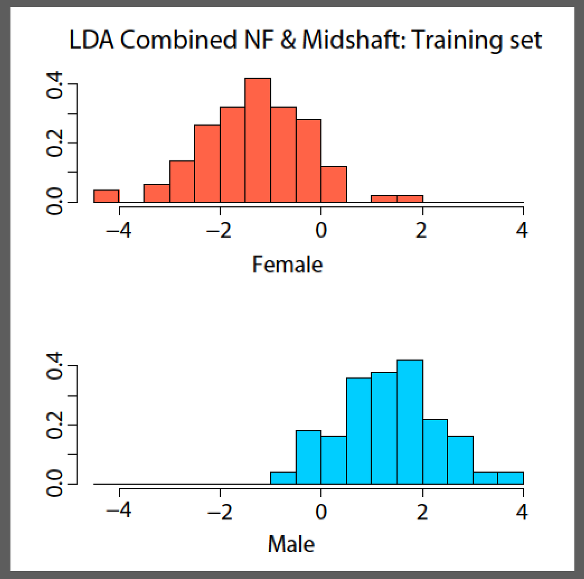

Figure 7. LDA of dimeter at nutrient foramen and midshaft

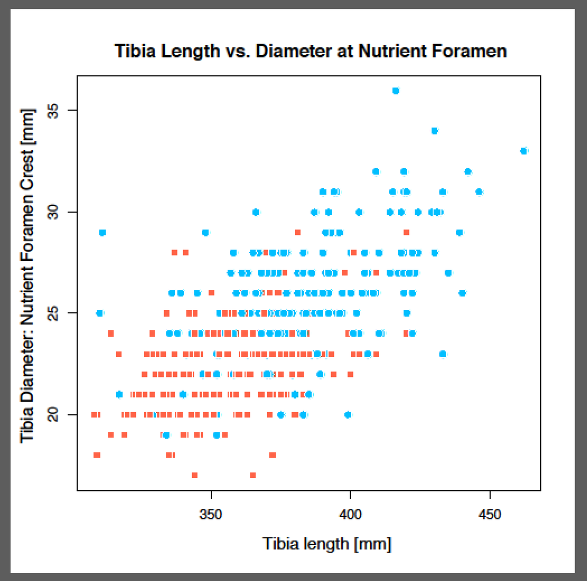

Figure 8. Distribution of female (red) and male (blue) diameters at nutrient foramen

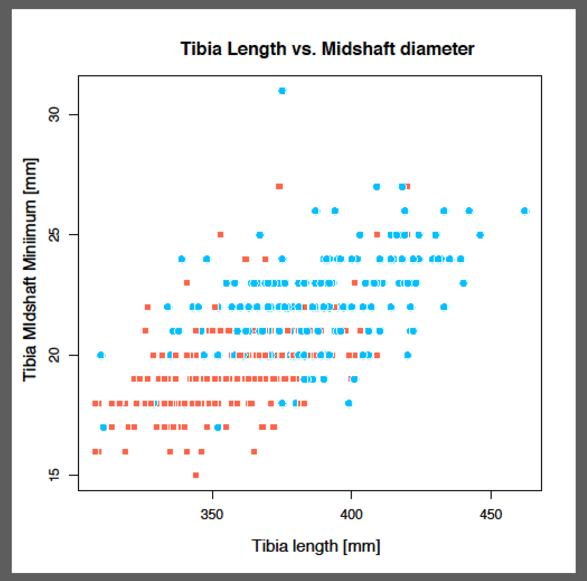

Figure 9.Distribution of female and male dimeters at midshaft

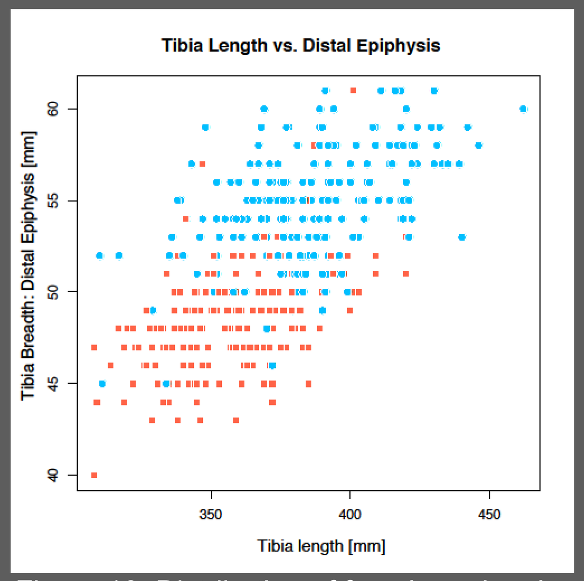

Figure 10. Distribution of female and male distal epiphysis breadths

Figure 2. Anterior-Posterior measurement at the nutrient

Figure 3. Medial-Lateral measurement at the nutrient

Figure 4. Anterior-Posterior measure-

Table 1. Combinations of Variables Tested

Nutrient Foramen – 90 Degrees	Nutrient Foramen – Crest
Anterior-Posterior diameter; Medial-lateral diameter at a 90 degree angle to the Anterior-posterior measurement; Circumference	Anterior-Posterior diameter; Medial-lateral diameter from the interosseous crest to a point directly opposite; Circumference
Mid-shaft	**Combination**
Maximum and Minimum diameter; Circumference	Nutrient Foramen – crest variables; Mid-shaft variables

Discussion

The results of this investigation show there is no significant advantage of determining sex based on measurements taken at the nutrient foramen compared to those taken at the midshaft. However, in cases involving fragmented remains, measurements taken at the level of the nutrient foramen would of course have more utility. Further analysis on the inter-observer error found with each landmark will contribute to our understanding of the utility and accuracy of these two metric standards. It is also well known that there are population differences in size and morphological characteristics of the skeleton. Thus there additionally needs to be an inter-population evaluation on the same discriminant function analysis. Understanding the global utility of these two standards will identify which standards should be employed.

Acknowledgements

We would like to thank Elizabeth Cottrell, Virginia Power, and Gene Hunt for organizing the NHRE internship. Additional thanks to Gene Hunt for assistance with statistical analyses. Funding thanks to Smithsonian Women's Committee and NSF REU Site, EAR-1560088.

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